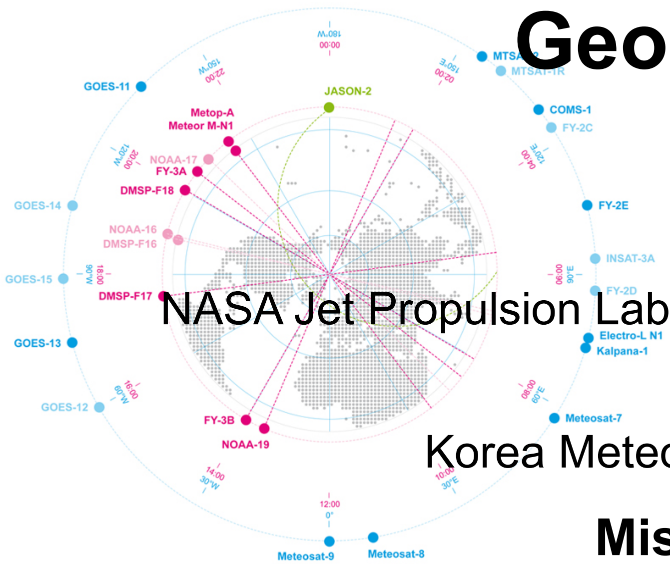


# Geostationary Satellite Measurements of Essential Ocean Variables

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**Coordination Group for Meteorological Satellites**


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CGMS

# Role of IOC-UNESCO (hereafter "IOC") in CGMS

- Coordination is pursued from an end-to-end perspective between meteorological satellite operators and user communities such as WMO and IOC-UNESCO (https://www.cgms-info.org/index_.php/cgms/index) to improve NWP accuracy and reliability
- Since 2011 (CGMS-39), IOC presented annual guidance on Essential Ocean Variables (i) sea surface temperature, (ii) ocean surface vector wind, (iii) sea surface topography, (iv) ocean biology, (v) sea surface salinity, (vi) sea ice, and (vii) sea surface waves
  - Ocean measurements were recorded with polar-orbiting satellites
  - Advised on importance of ocean measurements for improvement of skill in NWP

# Preparation of CGMS-46 IOC-WP-01

- CGMS SEC requested co-authors from CGMS Members (5 & 18 Sep 2017)
- Writing Team exchanged information by email

# Essential Ocean Variables

http://www.goosocean.org/index.php?option=com_content&view=article&id=14&Itemid=114)(assessed

## Physics

Sea Surface Waves
Surface Wind Stress
Sea Ice
Sea Surface Height
Sea Surface Temperature
Subsurface Temperature
Surface Current
Subsurface Current
Sea Surface Salinity
Subsurface Salinity
Ocean Surface Heat Flux

## Biogeochemistry

Oxygen
Nutrients
Transient Tracers
Particulate Matter
Nitrous Oxide
Stable Carbon Isotopes
Dissolved Organic Carbon
Ocean Color

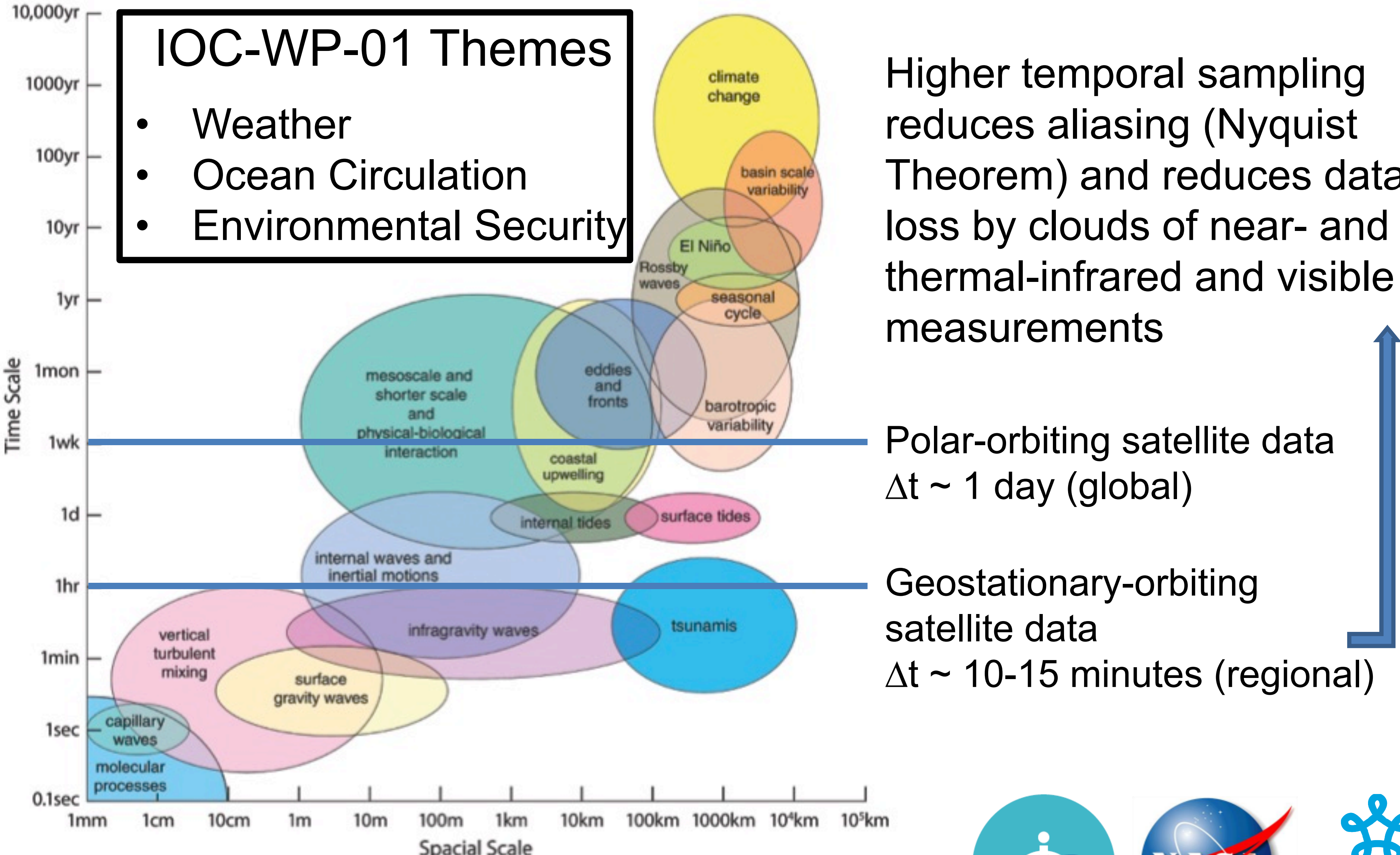
Previous CGMS IOC WPs

CGMS-46 WP

## Biology/Ecosystems

Phytoplankton Biomass
Zooplankton Biomass
Fish Abundance
Turtles, Birds, Mammals
Coral
Seagrass
Macroalgal Canopy
Mangrove
Microbe Biomass
Benthic Invertebrate

# Space-Time Distribution of Major Ocean Processes




Higher temporal sampling reduces aliasing (Nyquist Theorem) and reduces data loss by clouds of near- and thermal-infrared and visible measurements

Diagram courtesy of Dr. Bruce Howe, Univ. of Hawaii, 11Mar18

# SST and Weather (1)

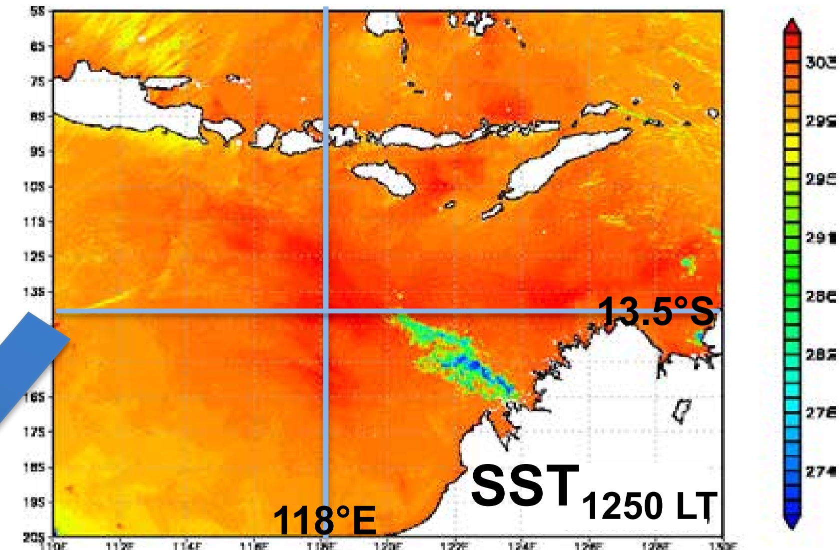
## Himawari-8 Daytime Heating

$\Delta SST_{time} = SST_{time} - SST_{ref}$

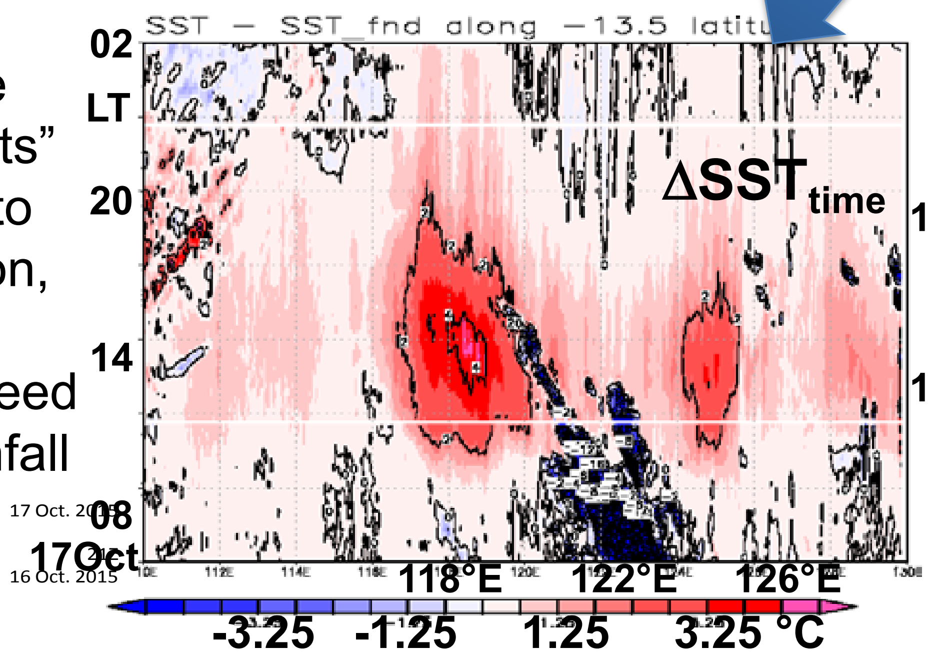
$SST_{ref} = \langle SST_{time} \rangle$ and time is 2300 – 0300 LT

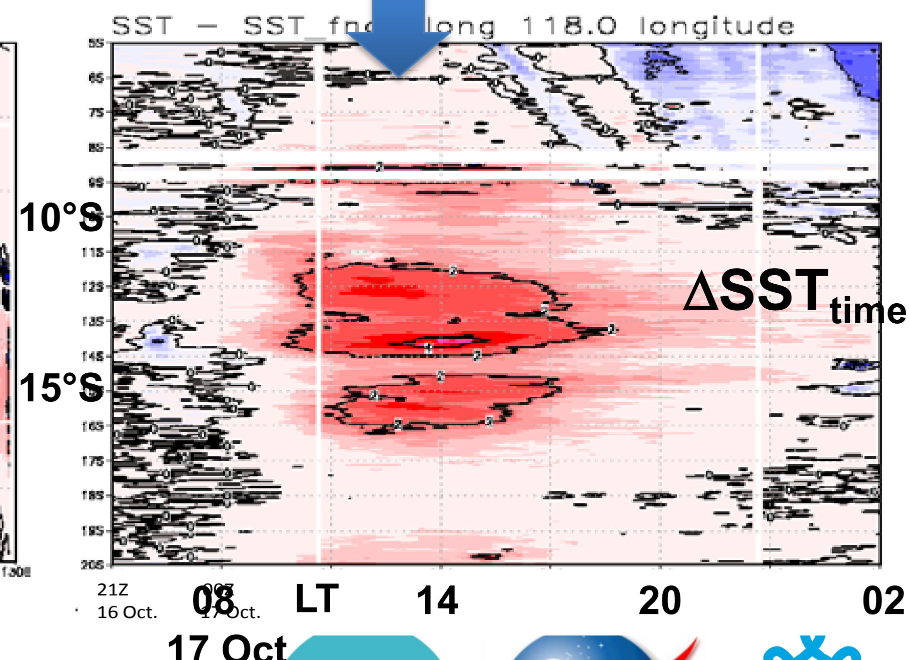
17 October 2017, northwest of Australia

LT = local time (+8 UTC)




Daytime "Hotspots" related to insolation, clouds, wind speed and rainfall



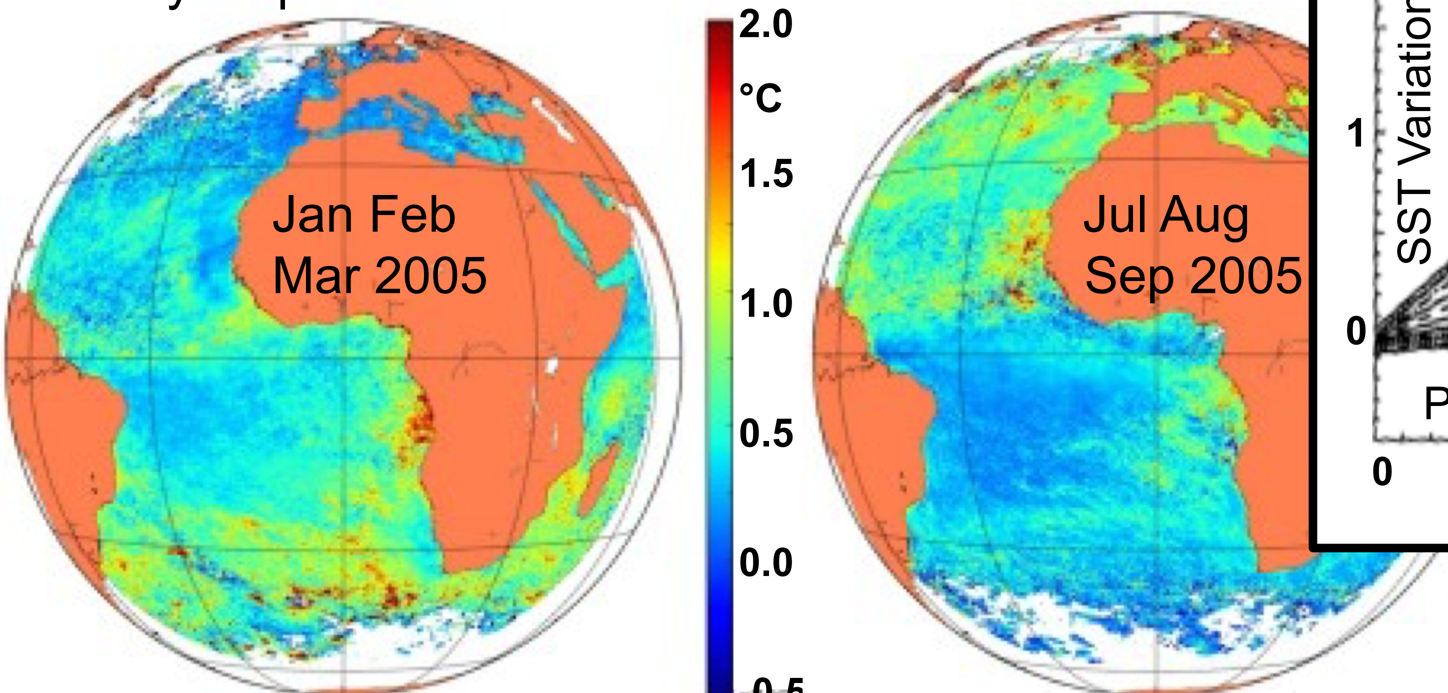


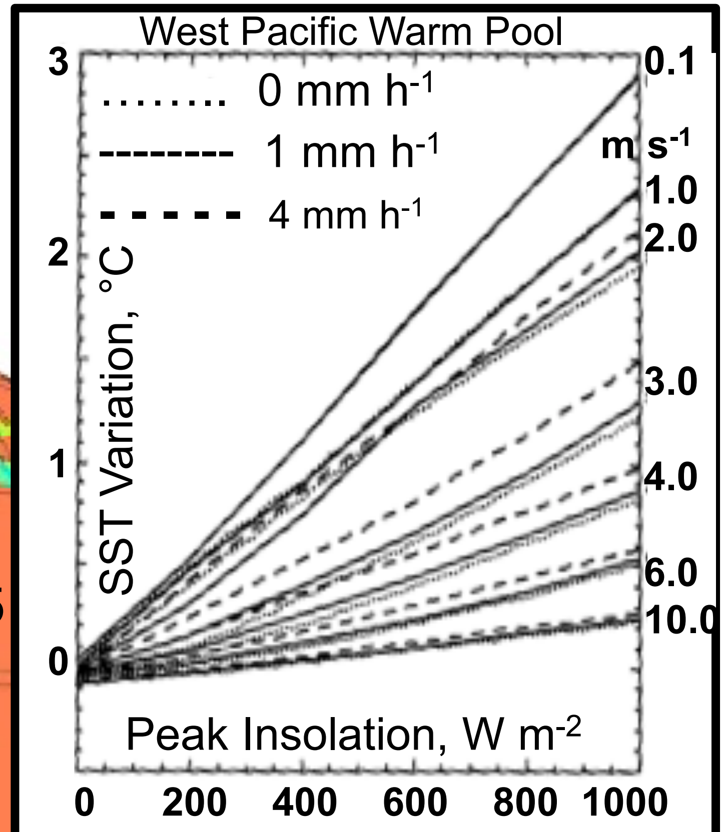

Kurihara (personal comm., 29Mar2018)
Kurihara et al. (2015)

# SST and Weather (2)

## Seasonal Cycle of MSG SEVIRI Diurnal SST Amplitude

- Dataset: Hourly reprocessed OSI SAF SST in space view (3 km at nadir)
- Time Interval: 2004 – 2012 and LST = local solar time
- $\Delta SST_{time} = SST_{time} - SST_{ref}$
- $SST_{ref} = \langle SST_{time} \rangle$ and time is 0300 - 0500 LST
- $\Delta SST_{max}$ = Max $\Delta SST_{time}$ during 1200 - 1600 LST
- Amplitude (= $\Delta SST_{max}$) varies with |**U**|
- Daily amplitudes reached 3-4 °C




Webster et al. (1996)

Gianelli (2017)
Saux Picart and Gianelli (2017)

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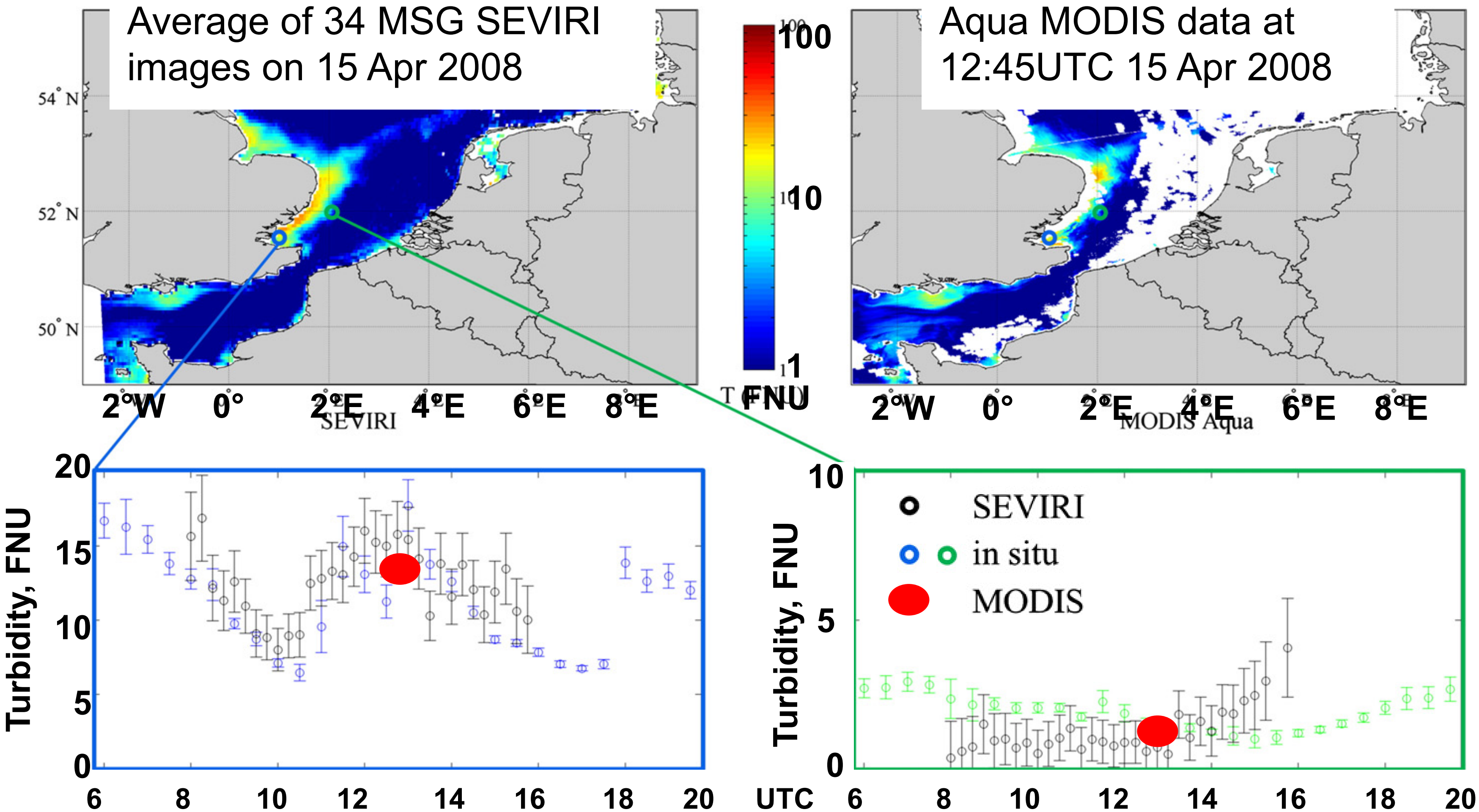
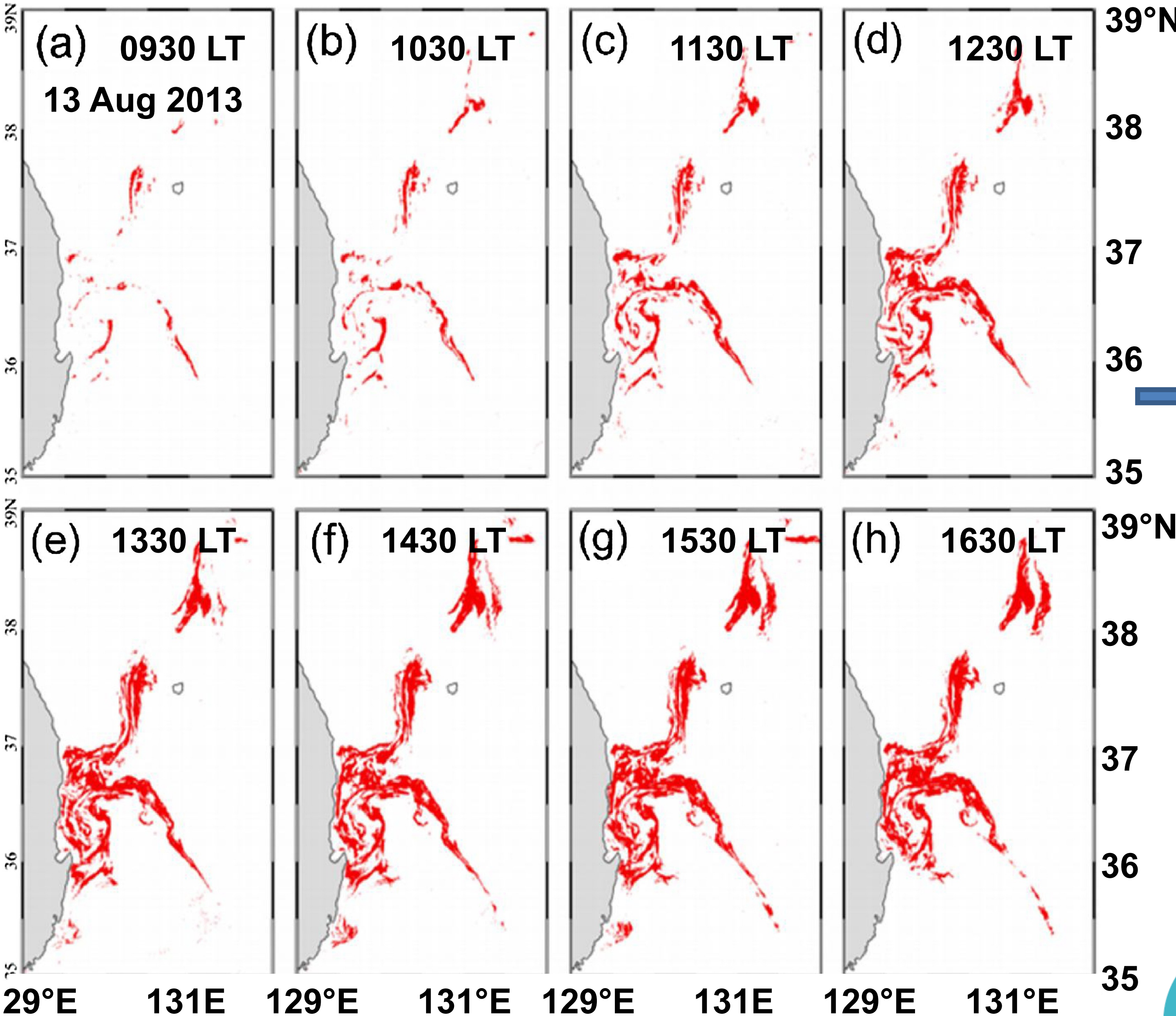
# Particulates and Health Security (1)




- Tidal current generated sediment resuspension and/or advection.
- SEVIRI error bars are related to aerosols.
- FNU = Formazin Nephelometric Unit

Ruddick et al. (2014)

# Harmful Algal Bloom (HAB) and Health Security (2)

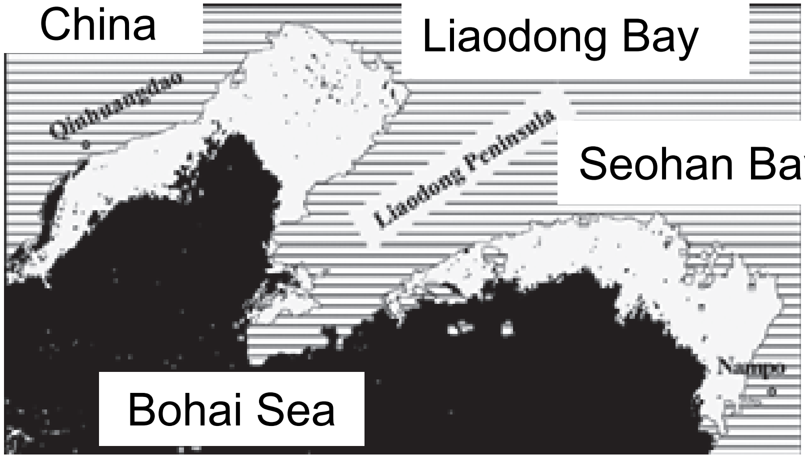



COMS GOCI chlorophyll-*a* concentration of *Cochlodinium* (*Margalefidinium*) *polykrikoides* (> 30 mg m$^{-3}$)
→ major HAB in Korean seas

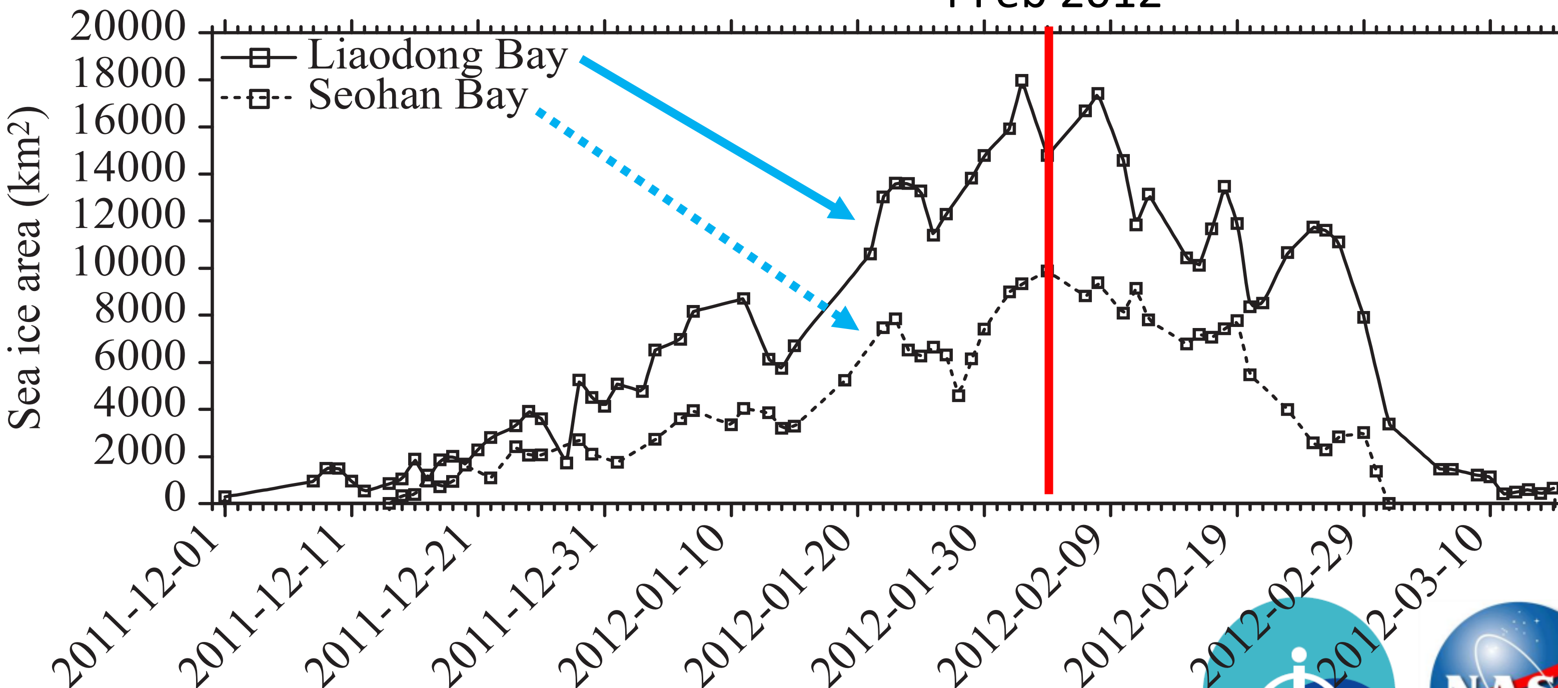
Daily vertical migration of *Cochlodinium polykrikoides*, begins at ~ 0800 LT when it floats to the surface, peaks at 1600, and then decreases.

Noh et al. (2018)

# Sea Ice and Economic Security




- COMS GOCI Sea Ice Area Coverage
- GOCI provides 8 hourly images per day
- 500-m resolution (compare passive µwave)
- Liaodong & Seohan Bays > 80% cloud free
- Southernmost latitudes for seasonal sea ice
- High spatial-temporal data mitigate hazards to navigation and offshore oil rigs




Lee and Lee (2016)

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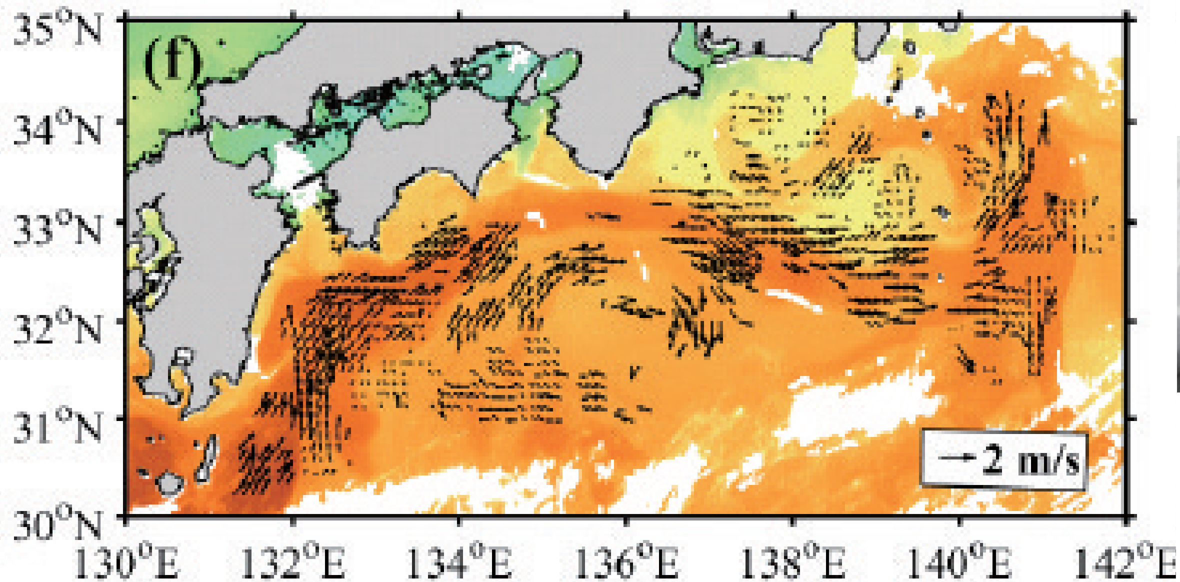
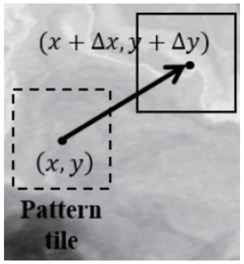
# Surface Current (1)




Feature Tracking Methods




- Maximum cross correlation
- Zero-mean sum of absolute dist.
- Zero-mean sum of squared dist.

Himawari-8 Advanced Himawari Imager brightness temperatures on 19 Sep 2016 at 13:40 UTC. Surface current vectors (ZSSD) of Kuroshio Current during 10:40 and 13:40 UTC (**3-h time interval**) on 19 Sep 2016.

| | Speed (m s$^{-1}$) | | Direction (°) | | Total number |
|---|---|---|---|---|---|
| | RMS | Bias | RMS | Bias | |
| ZSAD | 0.16 | $6.0 \times 10^{-2}$ | 6.7 | 1.2 | 77 |
| ZSSD | 0.15 | $4.0 \times 10^{-2}$ | 5.4 | 1.5 | 69 |
| MCC | 0.15 | $-4.7 \times 10^{-2}$ | 6.1 | 1.8 | 75 |

Comparison with satellite-tracked surface drifter measurements in April 2016.

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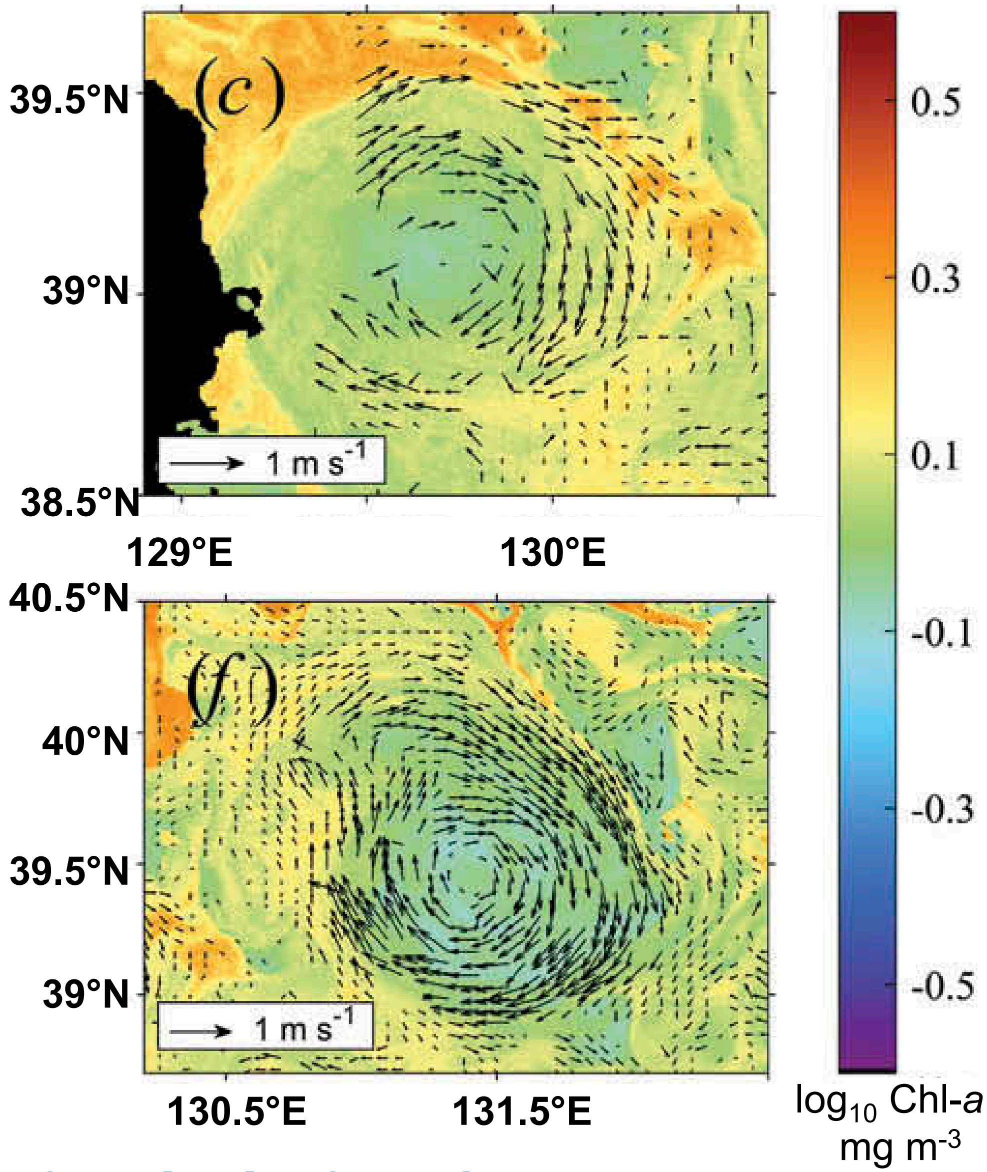
Kim et al. (2016)

# **Surface Current** (2)




- Low chlorophyll-*a* eddies at two locations measured by COMS GOCI at 1030 LT and 1230 LT (**2-hour time interval**) on 31 March 2011.
- Surface current vector computed with normalized maximum cross-correlation method of successive chlorophyll-*a* images.
- Remarkable analysis of high spatial structure and complexity of eddy currents, with 0.6 m $s^{-1}$ at outer boundary and 0.2 m $s^{-1}$ at inner boundary.

Park et al. (2016)

# Summary

- Geostationary-orbiting satellite measurements of EOVs will advance understanding of ocean-atmosphere interactions and improve predictability of oceanic processes

## Recommendations to be considered by CGMS

- Establish a 5-min temporal interval for measurements of EOVs from geostationary-orbiting satellites in response to a user survey (Kwiatkowska et al., 2016) and to yield a statistically robust 1-hour average for multiple applications
- Develop constellation of geostationary-orbiting satellites recording EOVs continuously along the equator with sufficient spatial overlap of field of view to conduct intercomparison tests
  - Establish a CEOS-CGMS working group for coordination of best practices
  - Discover efficient, effective methods to integrate EOV measurements from different geostationary-orbiting satellites and from polar-orbiting satellites

# Acknowledgements


- For this paper, DH represents IOC-UNESCO, which is a member of CGMS. The former WMO-IOC JCOMM supported IOC to accomplish CGMS Plenary Action 45-29. DH is deeply grateful to Dr. Jack Kaye, NASA Headquarters (HQ), for support to participate in CGMS-46, and thanks Dr. Albert Fischer, IOC, for the opportunity to represent the IOC at CGMS-46. DH appreciated the perspective review comments by Dr. Paula Bontempi, NASA HQ. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

# References

Gianelli, M. T. (2017) Etude de la variabilité spatio-temporelle du cycle diurne de la temperature de surface de la mer par l'observation satellitaire. Centre de Météorologie Spatial de Météo-France, 50 pp.

Kim, H.-A., K.-A Park and J.-E. Park (2016) Comparisons of algorithms for sea surface current retrieval using Himawari-8/AHI data. *Korean Journal of Remote Sensing*, *32*, 589-601.

Kurihara, Y., H. Murakami and M. Kachi (2015) Himawari-8 SST by JAXA. Paper presented at Satellite Oceanography User Workshop, 9-11 November 2015, Melbourne, Australia.

Kwiatkowska, E. J., K. Ruddick, et al. (2016) Ocean color opportunities from Meteosat Second and Third Generation geostationary platforms. *Ocean Science*, *12*, 703-713.

Lee, H.-S. and K.-S. Lee (2016) Capability of geostationary satellite imagery for sea ice monitoring in the Bohai and Yellow Seas. Journal of Marine Science and Technology, 24, 1129-1135.

Noh, J. H., W. Kim, S. H. Son, J.-H. Ahn and Y.-J Park (2018) Remote quantification of *Cochlodinium polykrikoides* blooms occurring in the East Sea using geostationary ocean color imager (GOCI). *Harmful Algae*, *73*, 129-137.

Park, J.-E., K.-A. Park, D. S. Ullman, P. C. Cornillon and Y.-J. Park (2016) Observation of diurnal variations in mesoscale eddy sea-surface currents using GOCI data. *Remote Sensing Letters*, *7*, 1131-1140.

Ruddick, K., G. Neukermans, et al. (2014) Challenges and opportunities for geostationary ocean color remote sensing of regional seas: A review of recent results. *Remote Sensing of Environment*, *146*, 63-76.

Saux Picart, S. and T. Gianelli (2017) Spatio-temporal variability of the seasonal cycle of sea surface temperature. Paper presented at EUMETSAT Meteorological Satellite Conference, 2-6 October 2017, Rome.

Webster, P. J., C. A. Clayson and J. A. Curry (1996) Clouds, radiation, and the diurnal cycle of sea surface temperature in the tropical western Pacific. *Journal of Climate*, *9*, 1712-1730.